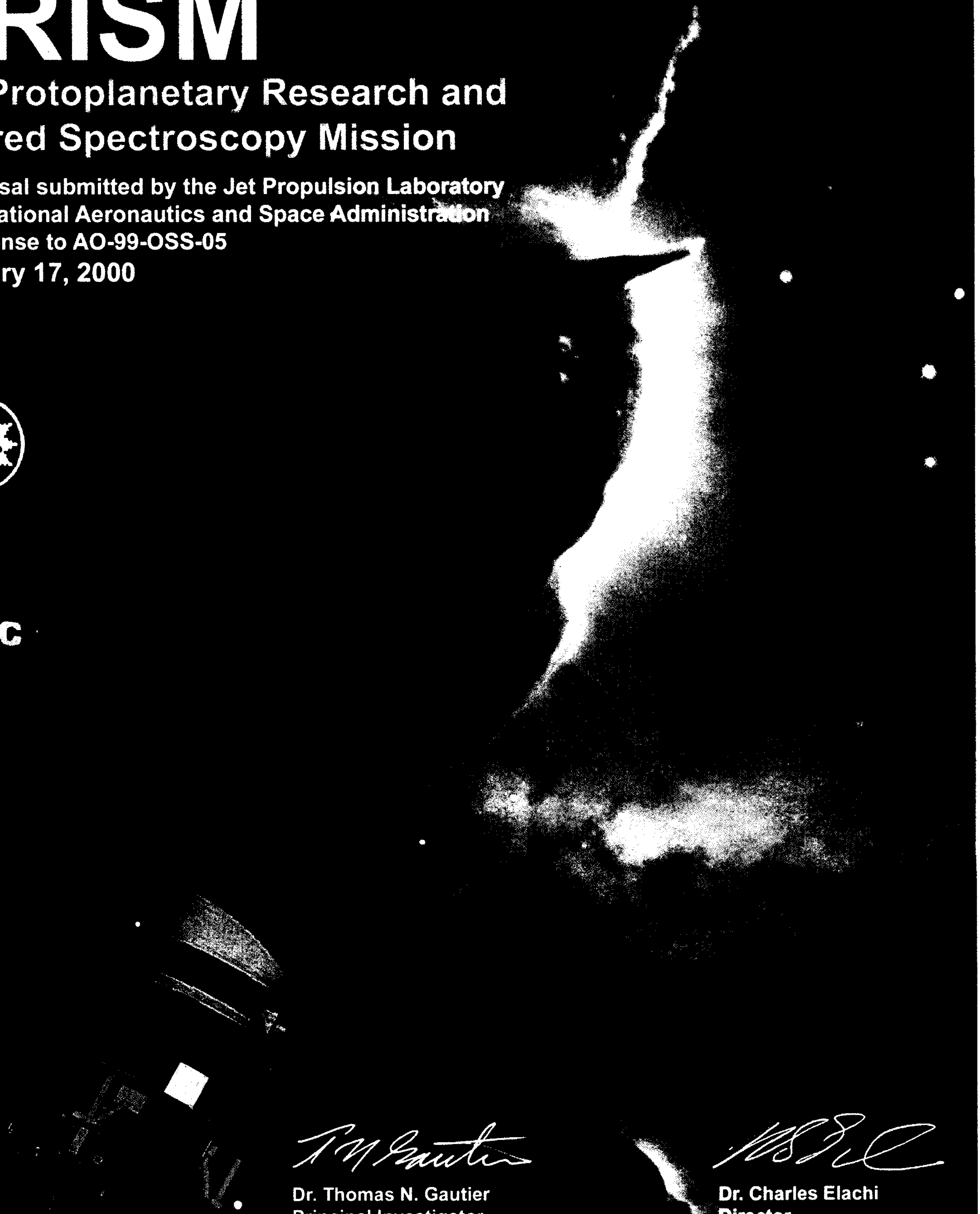
PRISM

The Protoplanetary Research and Infrared Spectroscopy Mission

A proposal submitted by the Jet Propulsion Laboratory
to the National Aeronautics and Space Administration
in response to AO-99-OSS-05

February 17, 2000



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PRISM Mission Summary

- The Protoplanetary Research and Infrared Spectroscopy Mission (PRISM) addresses pivotal questions in NASA's Astronomical Search for Origins. PRISM will use high-resolution near- and mid-infrared spectroscopy to characterize the interstellar and circumstellar ices, minerals, and molecules in the environments and protoplanetary systems around young stars. PRISM will also observe comets and other primitive solar system bodies to investigate the interstellar medium/solar nebula connection. Similar observations of nearby galaxies will determine the reservoirs available for planetary formation as a function of metallicity. With 60 times better sensitivity than the European Infrared Space Observatory and with spectral resolution and coverage superior to NASA's Space Infrared Telescope Facility (SIRTF), PRISM will provide the first complete near- and mid-IR spectra of hundreds of roughly solar mass young stellar objects, molecular cloud cores, evolved stars, galactic nebulae, and external galaxies. PRISM is, therefore, a complementary observatory to SIRTF and will serve as a pathfinder for high spatial resolution spectroscopy on the Next Generation Space Telescope. PRISM uses flight-ready technology and software from SIRTF and WIRE and a production-line, commercial spacecraft bus to dramatically reduce mission cost and risk.

- PRISM will operate from a Sun-synchronous, low-Earth orbit over the terminator as did IRAS, COBE and WIRE. The telescope, spectrometer optics, and detectors will be cooled by a two-stage, solid-hydrogen cryostat that is based on WIRE and SPIRIT III designs and has a predicted cryogen lifetime of 5.5 months. The three-axis stabilized spacecraft for PRISM will be an Orbital Sciences Corporation MicroStar bus. The PRISM spectrometers will use a cross-dispersed echelle design that was cryogenically proven at mid-IR wavelengths by the SIRTF Infrared Spectrometer now undergoing integration and test for flight. The baseline IR detector arrays, in 512×512-pixel format, will use proven detector materials and multiplexer designs.

- The PRISM proposal is currently in the step 1 review cycle for the NASA Small Explorer program. The selections for step 1 development are expected in June 2000.

PRISM Science

Primary Science: Protoplanetary Disks, and the Origins of the Earth and Life

The PRISM science program will concentrate on answering three major questions:

1. How do the physical and chemical conditions in protoplanetary disks arise and evolve?
2. Which circumstellar disks in nearby YSOs are likely to be forming planets that can support life and how common are such disks?
3. How abundant were water and prebiotic molecules in the primitive solar nebula, in comparison with those found in protoplanetary disks around young stars?

PRISM will also try to answer three additional questions:

4. How does carbonaceous material form and evolve before it is incorporated into protoplanetary disks?
5. How do shocks in molecular clouds affect planet forming dust and star-forming dense cores?
6. How do nearby galaxies compare to the Milky Way in their abundances of grains, mantle ice, and carbonaceous molecules?

PRISM will make contributions to NASA's Astronomical Search for Origins roadmap investigations

Goal	**Investigation**	**PRISM contribution**
Understand how stars and planetary systems form and evolve	Evolution of planetary disks	Significant
	Planet forming disks around young stars	Significant
Understand how life forms and evolves	Relative importance of sources of organics on early Earth	Significant
Determine whether habitable or life-bearing planets exist around other stars in the solar neighborhood	Climatological/geological effects on habitable zone and frequency of habitable planets	Minor
Understand how galaxies formed in the early universe	Early galaxies	Minor
	Chemical evolution	Minor

PRISM Mission Scenario

Instrument	33cm cassegrain telescope with 3 high resolution (R~2400) spectrometers covering the 2μm -20μm spectral region. Cryogenically cooled telescope and spectrometers.
Orbit	400Km circular, ~97° inclination over terminator
Launcher	Pegasus XL
Spacecraft	3 axis stabilized
Observation mode	Pointed, staring at individual targets
Lifetime	5.5 months
Data volume	~14,000 10 minute observations of a total of ~1800 objects

Comparison of Wavelength Coverage and Spectral Resolution of Space and Airborne Observatories

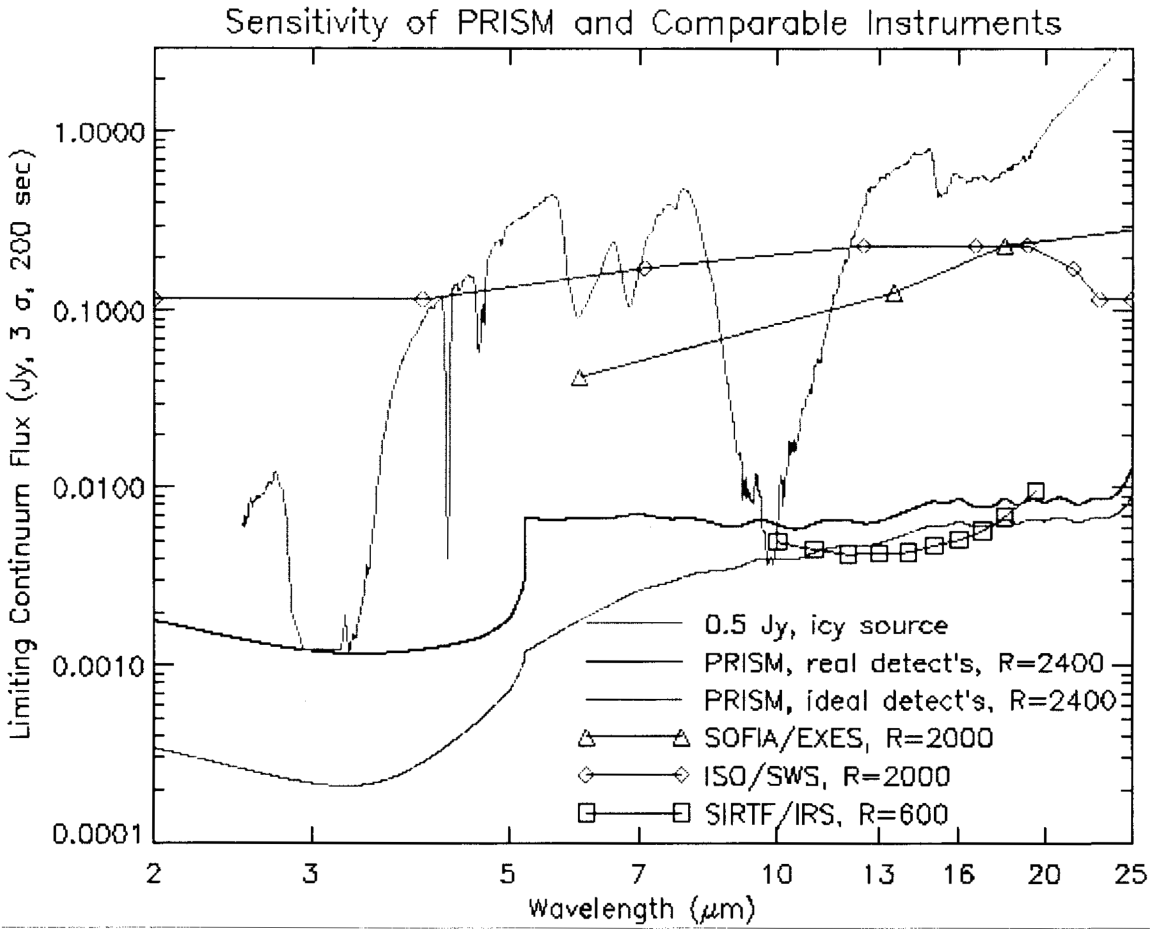
Instrument	Wavelength	Resolution	Location
PRISM	2 – 20	2400	Space
SIRTF/IRS	5 – 40	50	Space
SIRTF/IRS	10 – 38	600	Space
SOFIA/AIRES	17 – 210	10,000	Airborne, affected by atmospheric absorption
SOFIA/EXES	5 – 28	2,000, 10,000, 100,000	Airborne, affected by atmospheric absorption
ISO/SWS	2.4 – 45	1,000 – 2,000	Space

Telescope		Full Instrument	
Aperture	33 cm	Mass	155 Kg including the Cryostat
Focal length	1.2 m		
Operating temperature	17 K	Power	45 W
Spectrometers	Short λ	Mid λ	Long λ
Wavelength	2.1-5.5 μm	5.5-10.5 μm	10.5-20 μm
Spectral Resolution	2400	2400	2400
Spatial resolution	14″	14″	14″
Slit size	21″x98″	21″x98″	21″x98″
Cross Disperser	prism	grating	grating
Transmission	40%	30%	30%
Detector type	InSb	Si:As	Si:As
Detector format	512x512	512x512	512x512
Detector active area	512x512	384x384	384x384
Pixel size	50 μm, 7″	50 μm, 7″	50 μm, 7″
Detector temperature	17 K	7.5 K	7.5 K

PRISM Instrument characteristics.

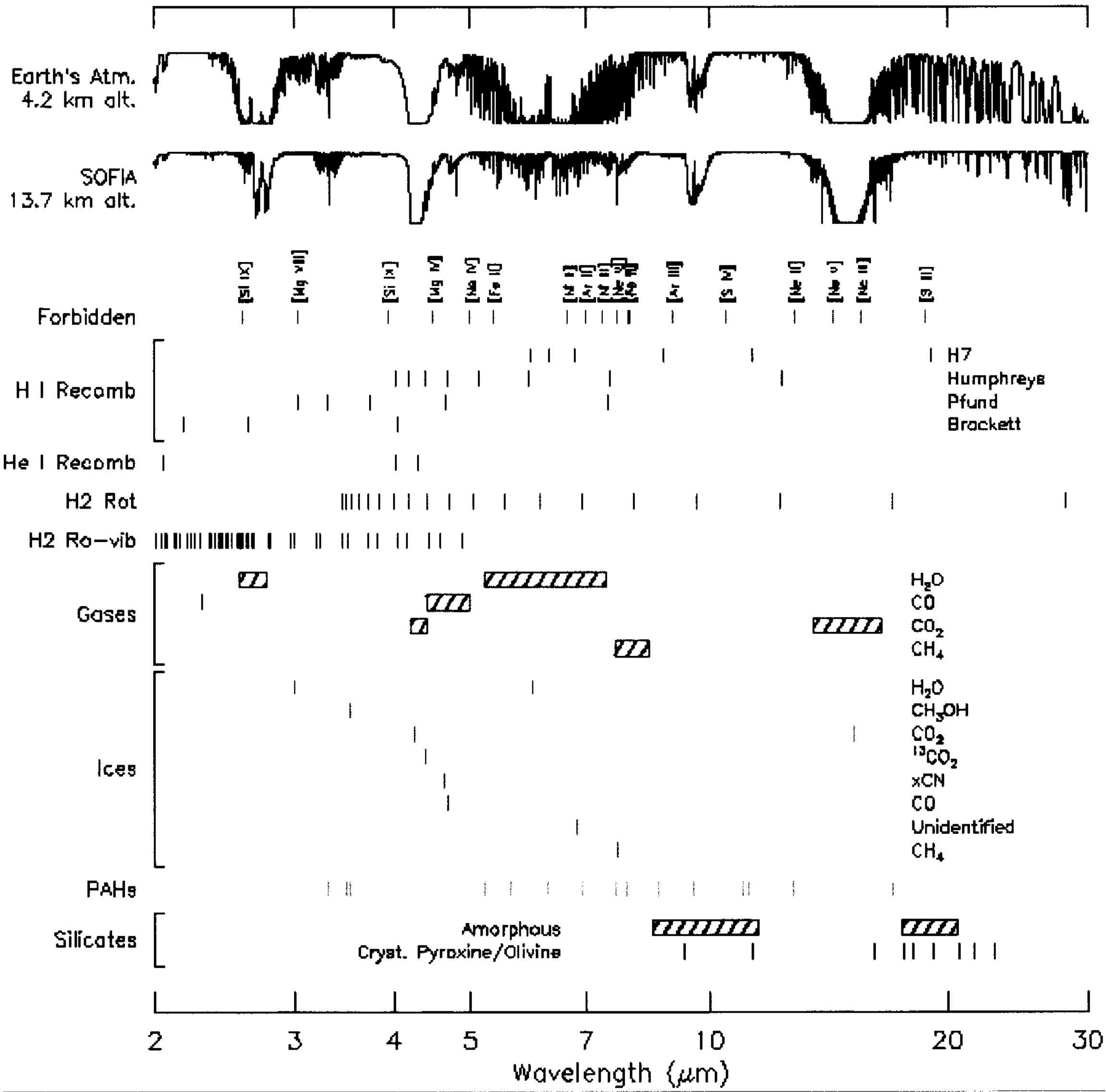
Target type	**YSOs & Stars**	**Disks**	**Comets**	**Extended regions**	**Galaxies**
λ Range (μm)	2.1-16	2.1-20	2.1-20	3-17	2.1-20
Spect Res. Δλ/λ	2,400	2,400	2400	1,500	2,400
Sensitivity (20 σ)	10-100 mJy	10-50 mJy	400 mJy	10 MJy/sr	250 mJy
Photometric Acc.	5%	5%	5%	10%	5%
Pointing Control (1σ radial)	5”	5”	5”	20”	5”
Point Stability (1σ radial / 200 s)	2”	2”	2”	10”	2”
# of Objects	600	120	30	70	550
# of Observations	2,000	2,400	1,200	3,500	2,000
Lifetime Req.	20 days	24 days	12 days	35 days	20 days
Data Volume	37 Gbits	45 Gbits	23 Gbits	66 Gbits	37 Gbits

PRISM performance requirements



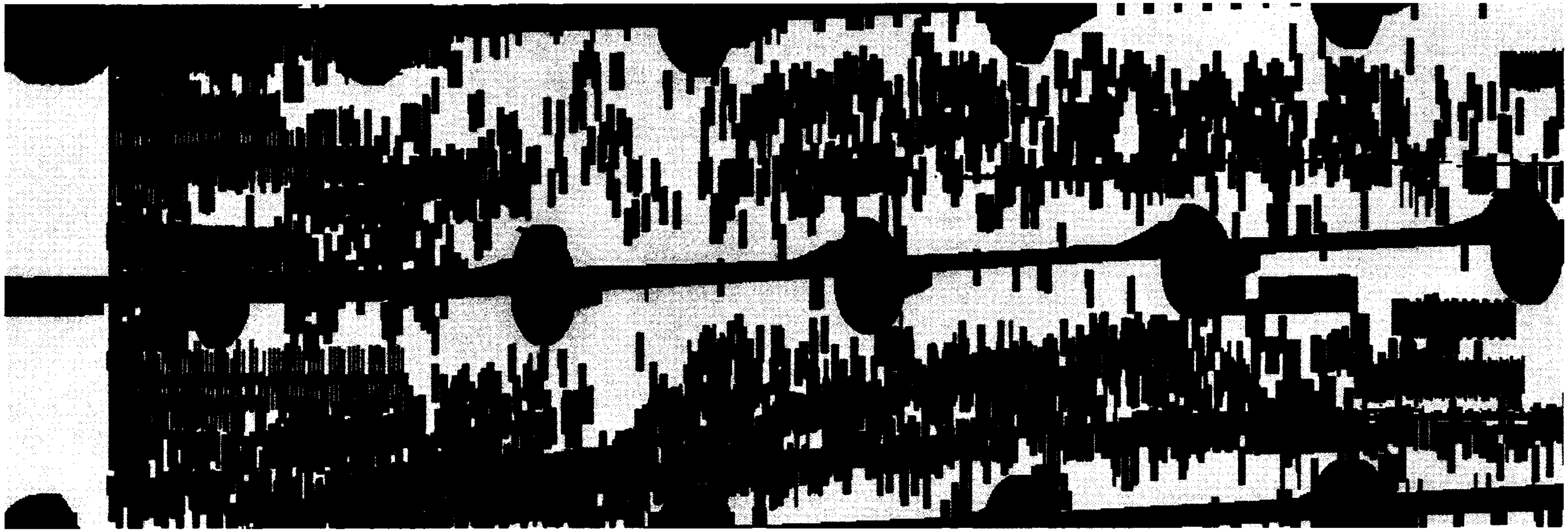
Comparison of the predicted sensitivity of PRISM with some other instrumentation and with the brightness of a 0.5 Jy celestial source showing many ice absorption features. Circumstellar disks around ~1 solar mass young stellar objects at the distance of the Taurus molecular cloud should present spectra with features and brightness similar to this source.

PRISM's predicted sensitivity in the 10-20 μm region is similar to SIRTF's in spite of the larger aperture and lower spectral resolution of SIRTF because the SIRTF detectors are expected to display significant dark current while the PRISM detectors are not.



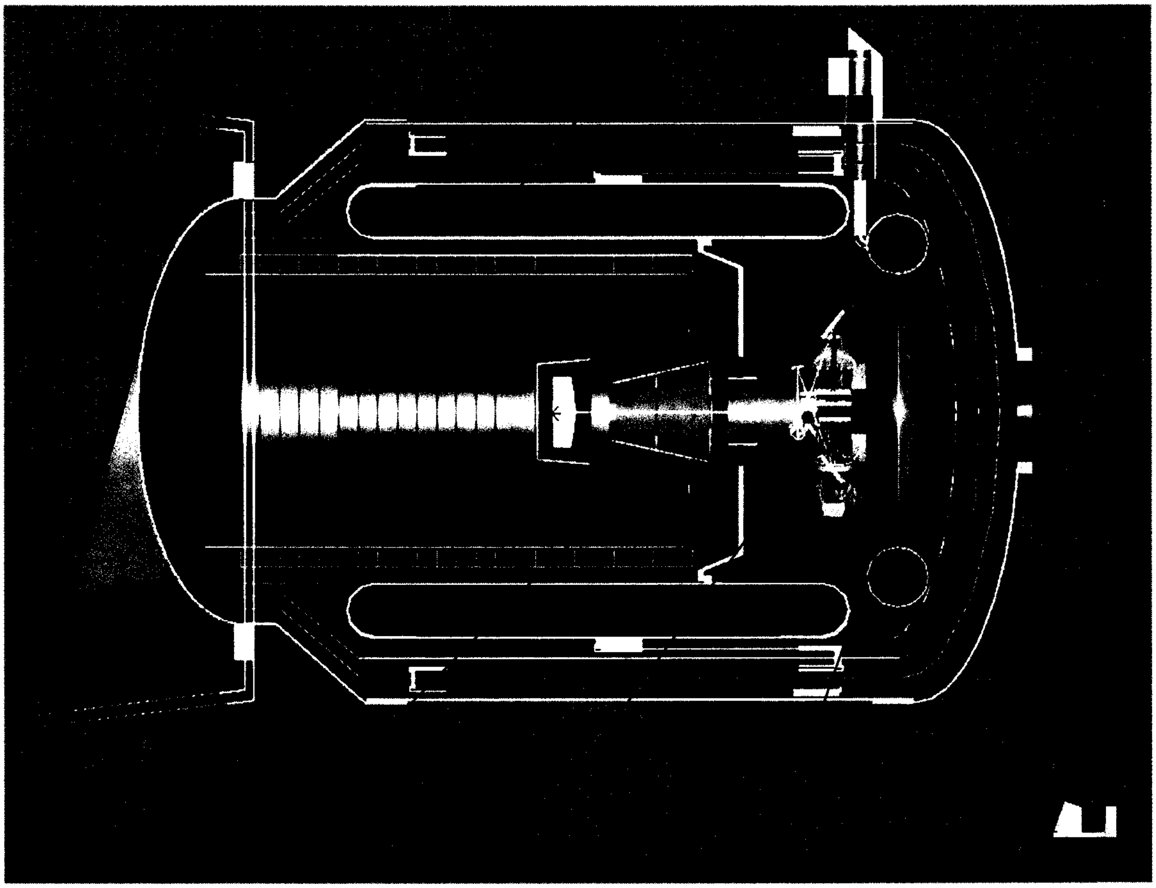
The location of important spectral features in the near and mid-IR region compared with the transmission of the Earth's atmosphere from mountain top and aircraft altitudes.

PRISM's location above the atmosphere will allow observation of biogenically important species like CO_2 and H_2O without interference from atmospheric absorptions.



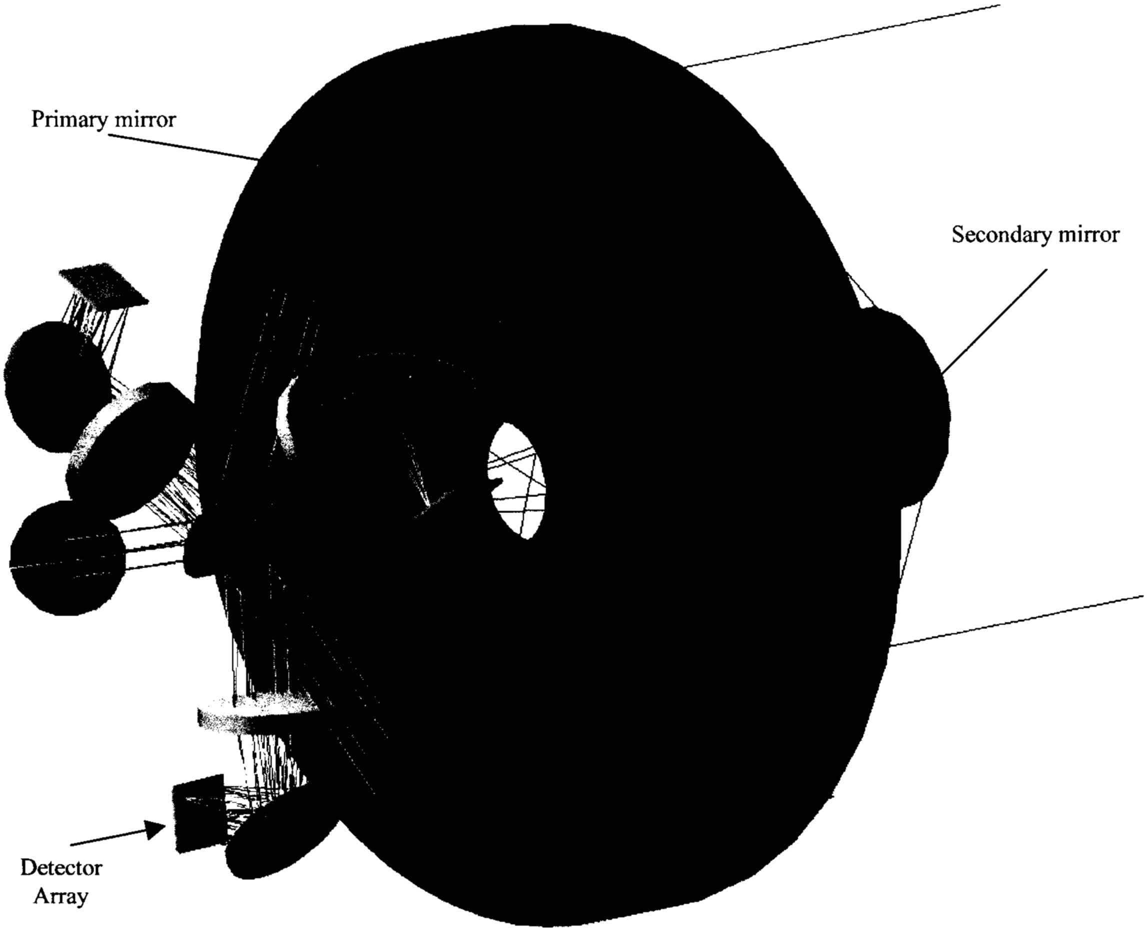
A sample PRISM mission plan for a September 2003 launch. The horizontal axis is mission orbit number spanning 4.5 months. The vertical axis is position in the orbit with the ascending node crossing at the bottom and the descending node in the center. Five 200 second observations of each of 1500 objects were scheduled and are shown at the locations in their orbits as red and blue bars. Blue for galactic objects and red for extragalactic. The black ovals and bands in the background represent the locations of the moon and ecliptic plane as visible to PRISM.

PRISM will make use of existing mission planning tools which have been developed for WIRE and SIRTF. A sample mission plan generated with the WIRE planner is shown above. The SIRTF scheduling and command generation software will be used to produce command sequences based on this ort of plan.

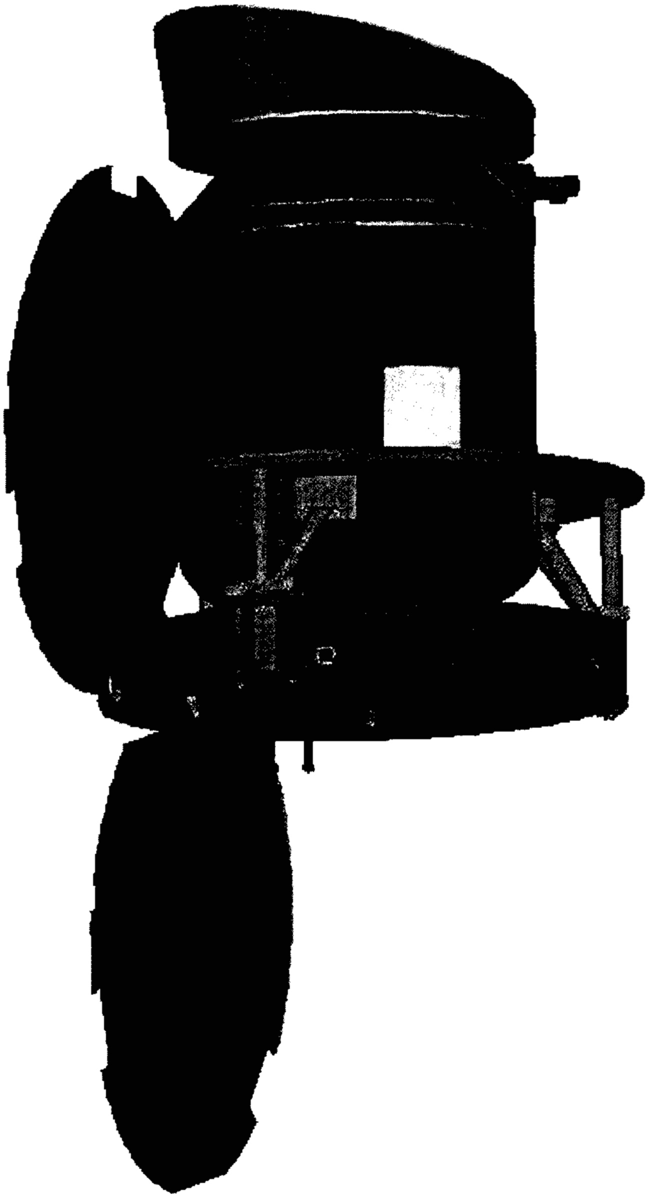


A cutaway illustration of the telescope, spectrometers and cryogenic system.

The Space Dynamics Laboratory of Utah State University will design and fabricate the PRISM cryostat, telescope and spectrometers. The infrared detector arrays will be supplied by Raytheon Systems Company.



A solid model illustration of the PRISM optical system. The three infrared spectrometers as situated behind the telescope. The three entrance slits are located close to each other near the center of PRISM's field of view. This picture shows the short wavelength spectrometer with a grating cross disperser rather than the planned prism corss disperser.



The PRISM observatory fully deployed into its operational configuration. The instrument shown in figure 3 is now mounted to the top of the PRISM spacecraft and the circular solar panels have been deployed from their stowed, launch location on the bottom side of the spacecraft.

Orbital Sciences Corporation will supply a spacecraft from their Microstar production line which has been customized for PRISM with an upgraded pointing system.